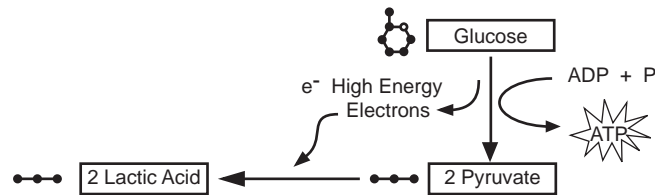


# Energy and Muscle Contraction

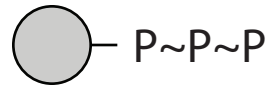
## A Primer on the *Energetics of Muscle Contraction* and *Oxygen Debt*



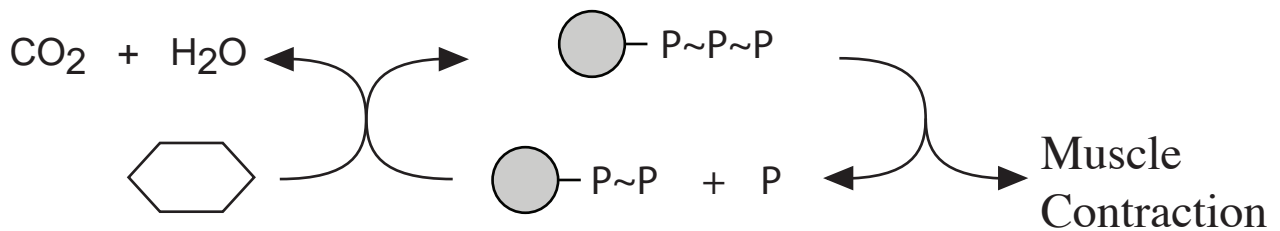
*by Noel Ways*

# Energy and Muscle Contraction

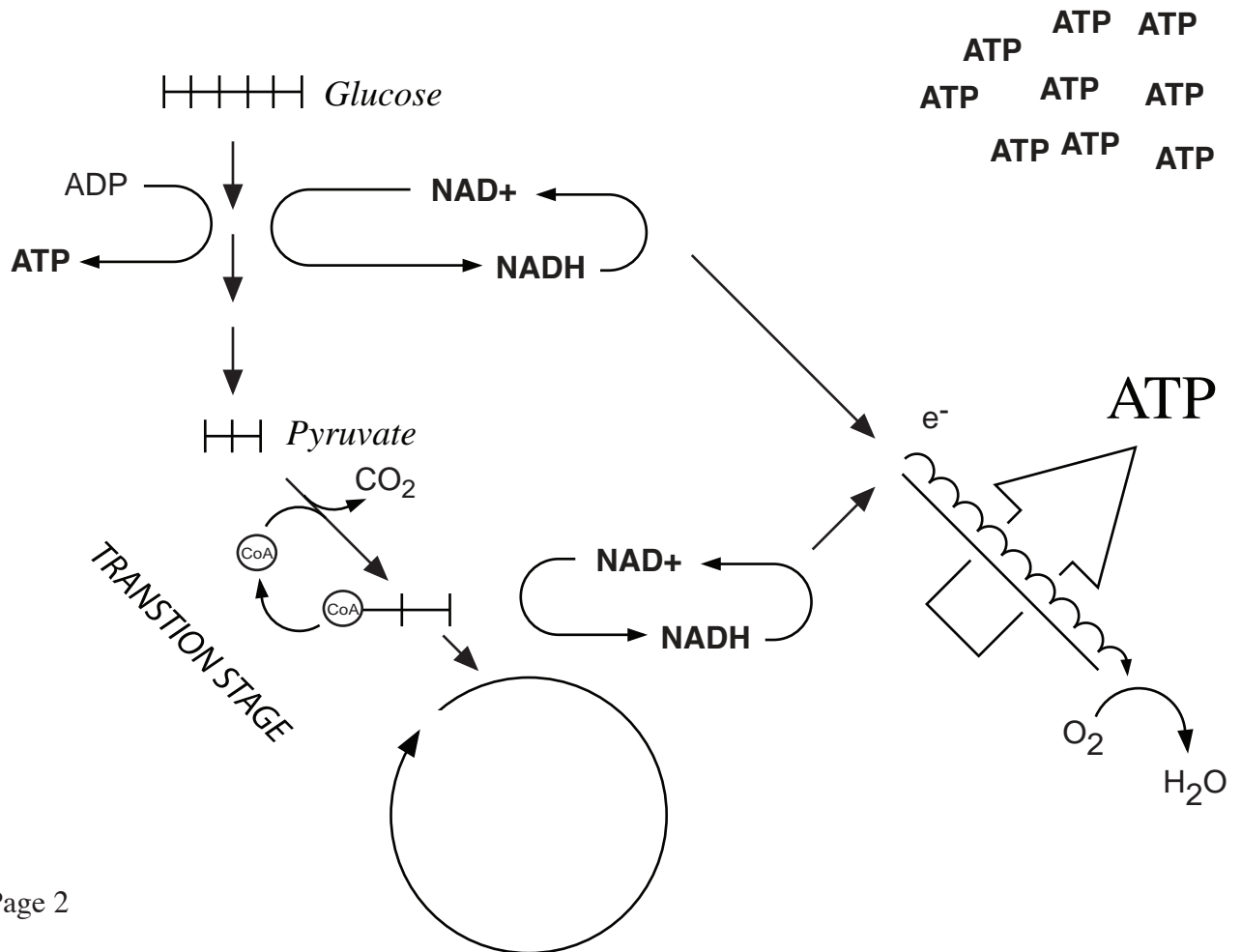
In order for a muscle to contract ("Sliding Filament Theory") abundant ATP is required. ATP is the chemical energy form usable by cells, where the energy is available through the high energy phosphate bonds ( $\sim$ ). The molecule can be abbreviated:




The energy needed for muscle contraction comes from breaking a "high energy bond" between two phosphates. In order for this process to continue the ADP and P will need to have the high energy bond reformed. The energy for resynthesizing ATP comes from Glycolysis and Cellular Respiration



## Glycolysis and Cellular Respiration, a Review



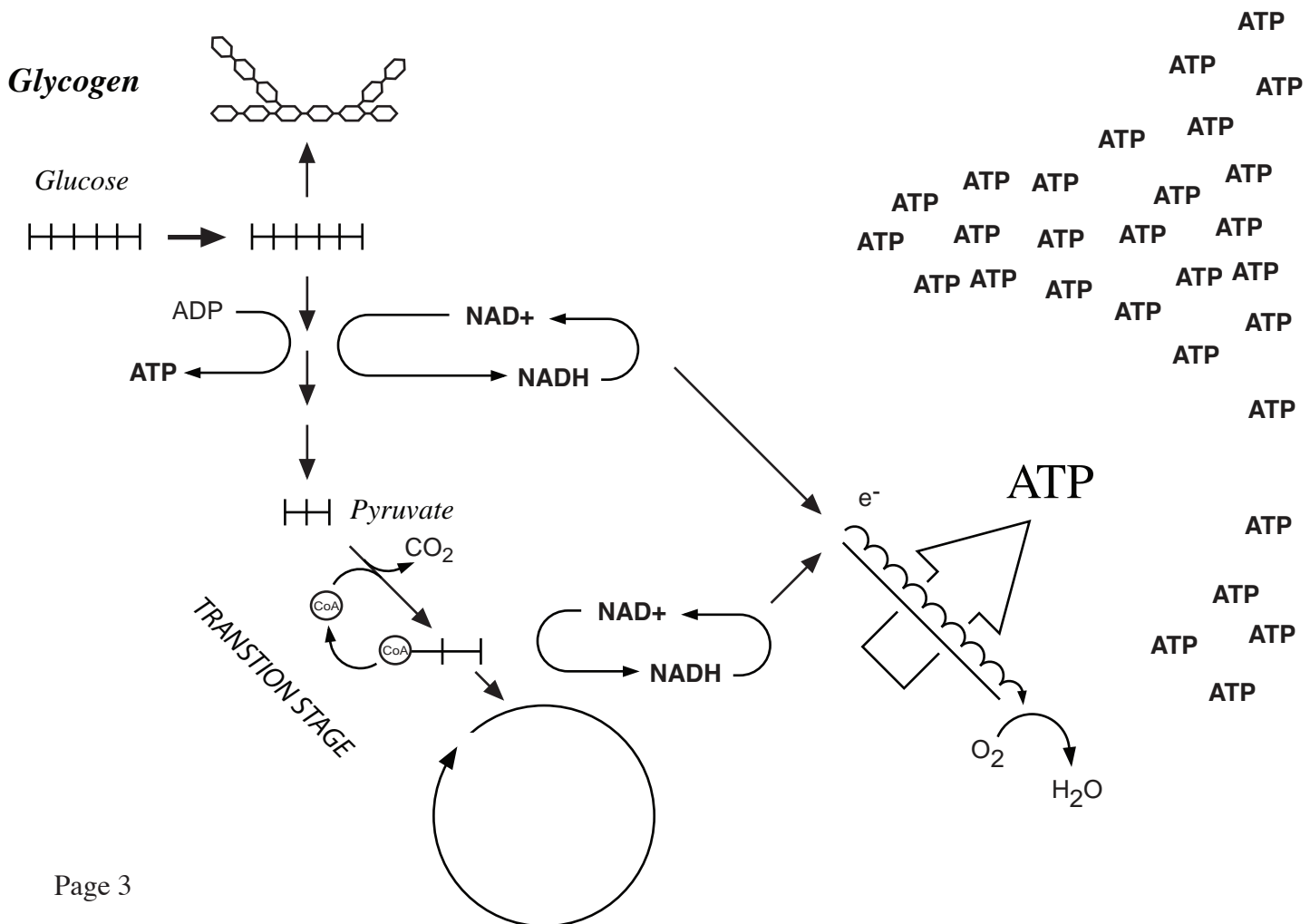
In order for cellular respiration to occur, two molecules need to be provided:

1. Something to be oxidized (such as glucose: )
2. Something to be reduced (oxygen)

The substance that is oxidized supplies the “high energy electrons” to be processed for ATP synthesis purposes. The substance to be reduced (O<sub>2</sub>) will receive the electrons once in a “low energy state”. The oxygen will be reduced to water, the “final electron acceptor”.

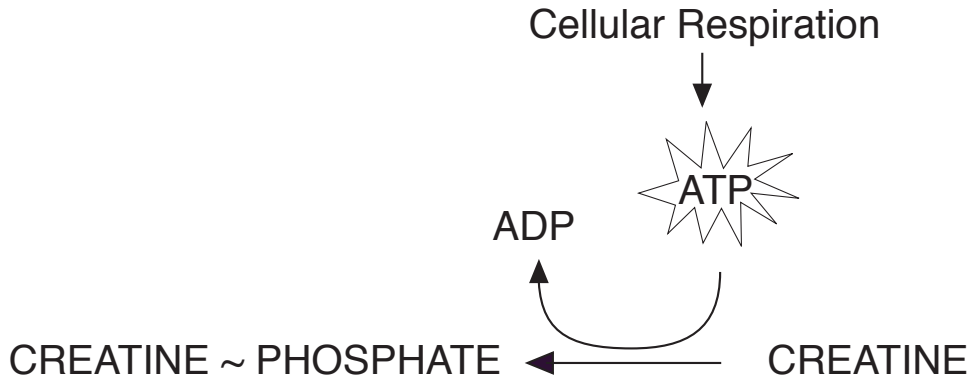
Assuming a person is adequately nourished, the cellular respiration will proceed at a rate that is directly proportional to oxygen delivery. If oxygen delivery increases, ATP production increases. If oxygen delivery decreases, ATP production decreases. ATP will be produced by cellular respiration is direct proportion to oxygen delivery.

Suppose more energy is consumed than is needed to meet the metabolic needs of the body? During such times, energy may be stored. Note, first that glucose can be stored as glycogen. Note, secondly that ATP is accumulating in the sarcoplasm.

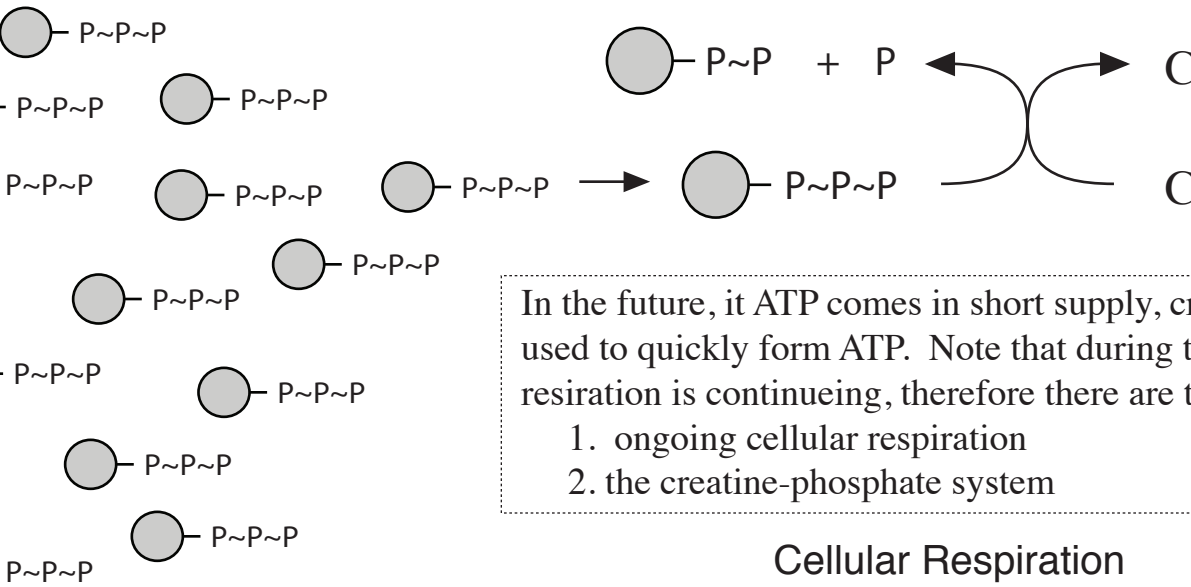
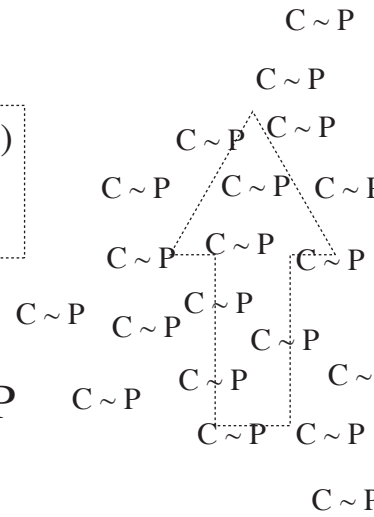


# Creatine-Phosphate System

When more ATP is produced than necessary to meet the metabolic demands of the body, the high energy bonds can be stored in another form: Creatine phosphate.

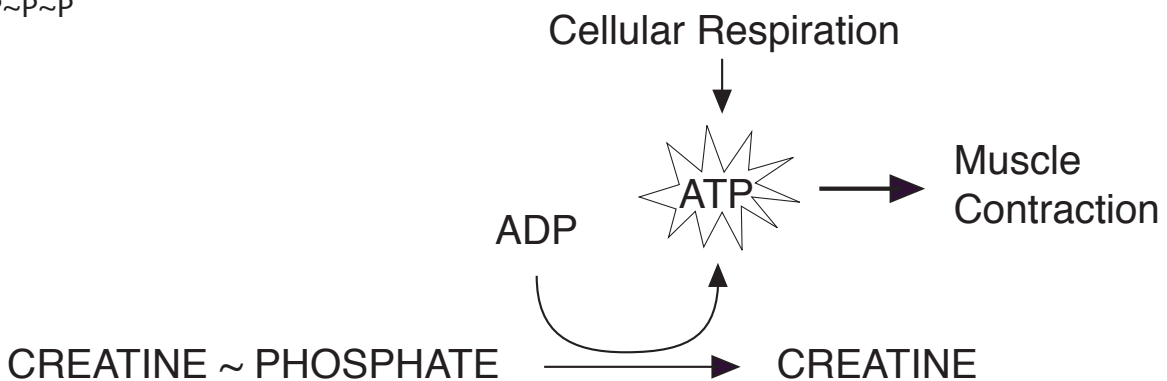


Below excess ATP, or more importantly, high energy phosphate bonds ( $\sim P$ ) are now stored in the form of creatine~phosphate ( $C \sim P$ ). As the process continues, the creatine-phosphate “bank account” increases.

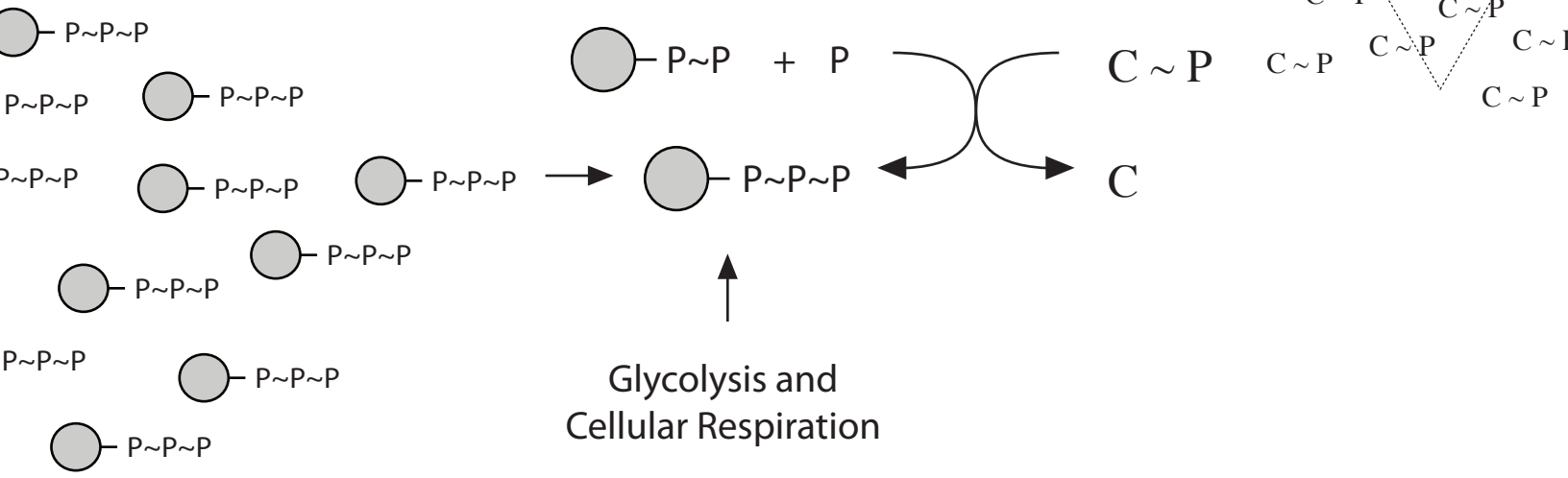


In the future, if ATP comes in short supply, creatine phosphate can be used to quickly form ATP. Note that during this time, cellular respiration is continuing, therefore there are two supplies of ATP:

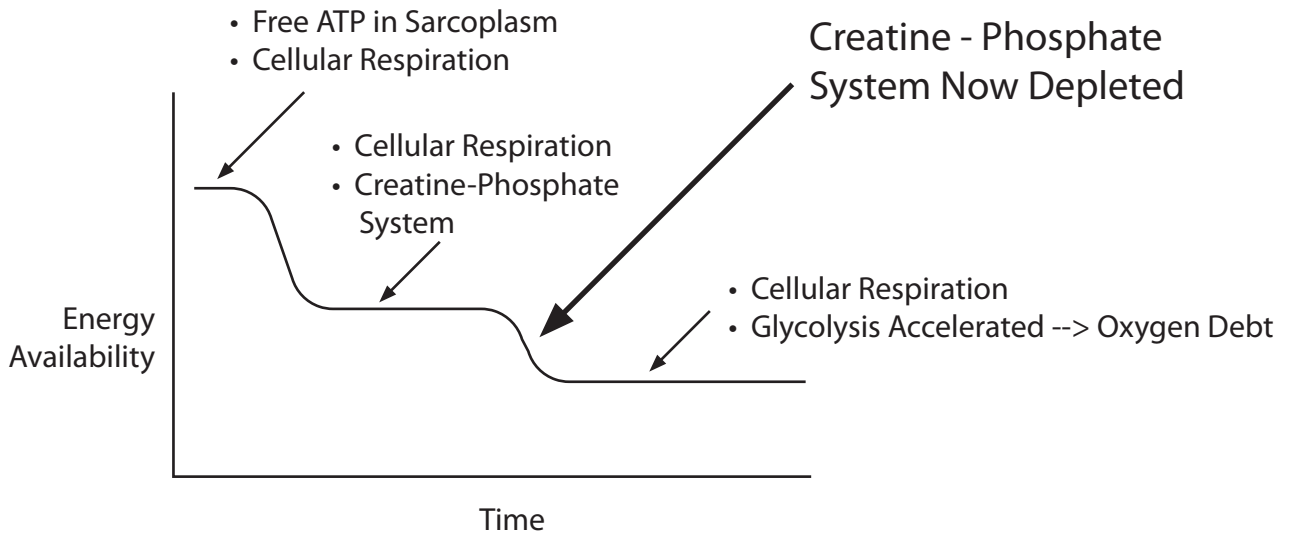
1. ongoing cellular respiration
2. the creatine-phosphate system



As strenuous exercise continues, ATP will continue to be drawn from two sources, the on-going glycolysis, and cellular respiration as well as the creatine phosphate system. But and the exercise continues the stored creatine phosphate will be depleted until gone.

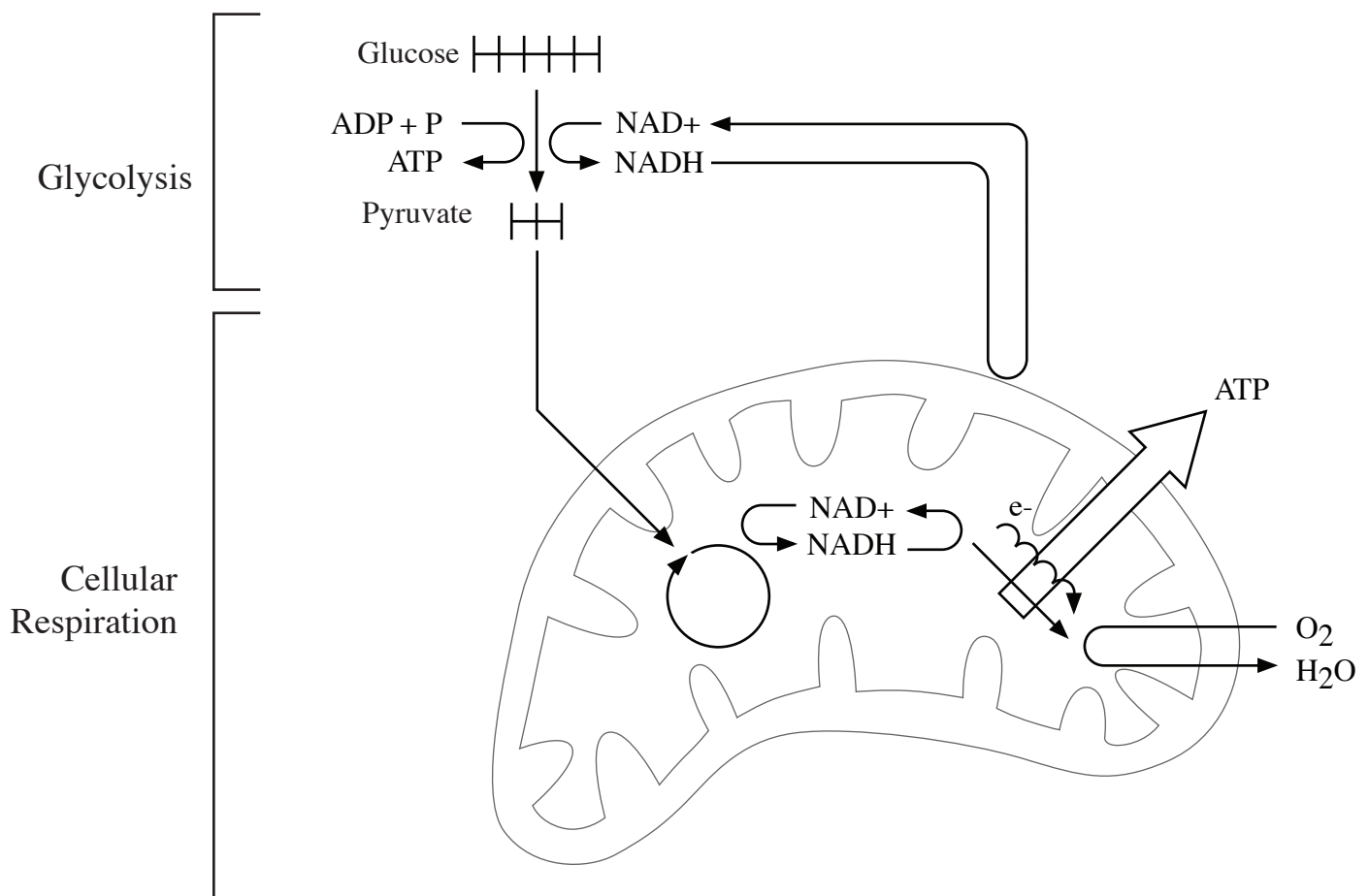


When creatine phosphate is no longer available, the second “physiological wall” is hit and the person will ostensibly have to go slower.



Once free ATP in the cytoplasm is gone, and once the creatine-phosphate system is “empty” ATP production is becoming limited. We also know that the rate of cellular respiration is directly dependent upon oxygen availability. ATP production will go at a faster or slower rate depending upon oxygen delivery. All that the mitochondrion does is directly dependent upon oxygen availability.

Glycolysis, however, is not cellular respiration. Glycolysis does not occur in the mitochondria, but in the cytoplasm. Therefore it is possible that glycolysis may be accelerated independently of oxygen delivery. When ATP production occurs independent of oxygen, it is said to be anaerobic.





After strenuous exercise has ended, free intracellular ATP is depleted, creatine~phosphate is used up, and there is a lactic acid build up holding electrons temporarily. All of these need to be addressed.

1. Ventilation continues accelerated for heightened oxygen delivery. ATP continues to be synthesized to meet cellular needs, as well as address the issues listed below.
2. Lactic acid, a temporary electron acceptor, is oxidized and NAD<sup>+</sup> is reduced to NADH. The electrons may now be delivered to the electron transport chain and received by O<sub>2</sub> ("Oxygen debt is paid off").
3. As ATP continues to be made, Creatine~Phosphate concentration rises giving rise again to a ready supply of Phosphates (~P) for quick ATP synthesis.
4. Free ATP begins to accumulate in sarcoplasm of cell.

